3.0 Development of Dispersion Factors Using ISCST3

In assessing the potential risk from an emissions source, one of the properties that must be evaluated is the ability of the atmosphere in the local area to disperse the chemicals emitted. When a chemical is emitted, the resulting plume moves away from the source and begins to spread both horizontally and vertically at a rate that is dependant on local atmospheric conditions. The more the plume spreads (i.e., disperses), the lower the concentration of the emitted chemicals will be in the ambient air. Dispersion models are designed to integrate meteorological information into a series of mathematical equations to determine where the material travels after release and how fast the material is ultimately removed from the atmosphere.

IWAIR uses dispersion factors to relate an emission rate to an air concentration at some specified location. A dispersion factor is essentially a measure of the amount of dispersion that occurs from a unit of emission. Dispersion modeling is complex and requires an extensive data set; therefore, the IWAIR model has incorporated a database of dispersion factors. For IWAIR, dispersion was modeled using a standardized unit emission rate ($1 \ \mu g/m^2$-s) to obtain the air concentration (referred to as a dispersion factor) at a specific point away from the emission source. The unit of measure of the dispersion factor is $\mu g/m^3$ per $\mu g/m^2$-s. The most important inputs to dispersion modeling are the emission rate, meteorological data, the area of the WMU, the height of the WMU relative to the surrounding terrain, and the location of the receptor relative to the WMU. The default dispersion factors in IWAIR were developed for many separate scenarios designed to cover a broad range of unit characteristics, including

- ■ 60 meteorological stations, chosen to represent the different climatic and geographical regions of the contiguous 48 states, Hawaii, Puerto Rico, and parts of Alaska;

- ■ 4 unit types;

- ■ 17 surface areas for landfills, land application units, and surface impoundments, and 11 surface areas and 7 heights for waste piles;

- ■ 6 receptor distances from the unit (25, 50, 75, 150, 500, 1,000 meters); and

- ■ 16 directions in relation to the edge of the unit (only the maximum direction is used).

The default dispersion factors were derived by modeling many scenarios with various combinations of parameters, then choosing as the default the maximum dispersion factor for each WMU/surface area/height/meteorological station/receptor distance combination.

Based on the size and location of a unit, as specified by the user, IWAIR selects an appropriate dispersion factor from the default dispersion factors in the model. If the user specifies a unit surface area or height that falls between two of the sizes already modeled, IWAIR used an interpolation method to estimate a dispersion factor based on the two closest model unit sizes.

The ISCST3 dispersion model (U.S. EPA, 1995) was selected to develop the dispersion factors in IWAIR. ISCST3 was chosen because it can provide reasonably accurate dispersion estimates for both ground-level and elevated area sources. Section 3.1 describes the development of the dispersion factor database used in IWAIR. Section 3.2 describes the interpolation method.

3.1 Development of Dispersion Factor Database

Figure 3-1 summarizes the process by which the dispersion factor database was developed. Each step is described in the following subsections.

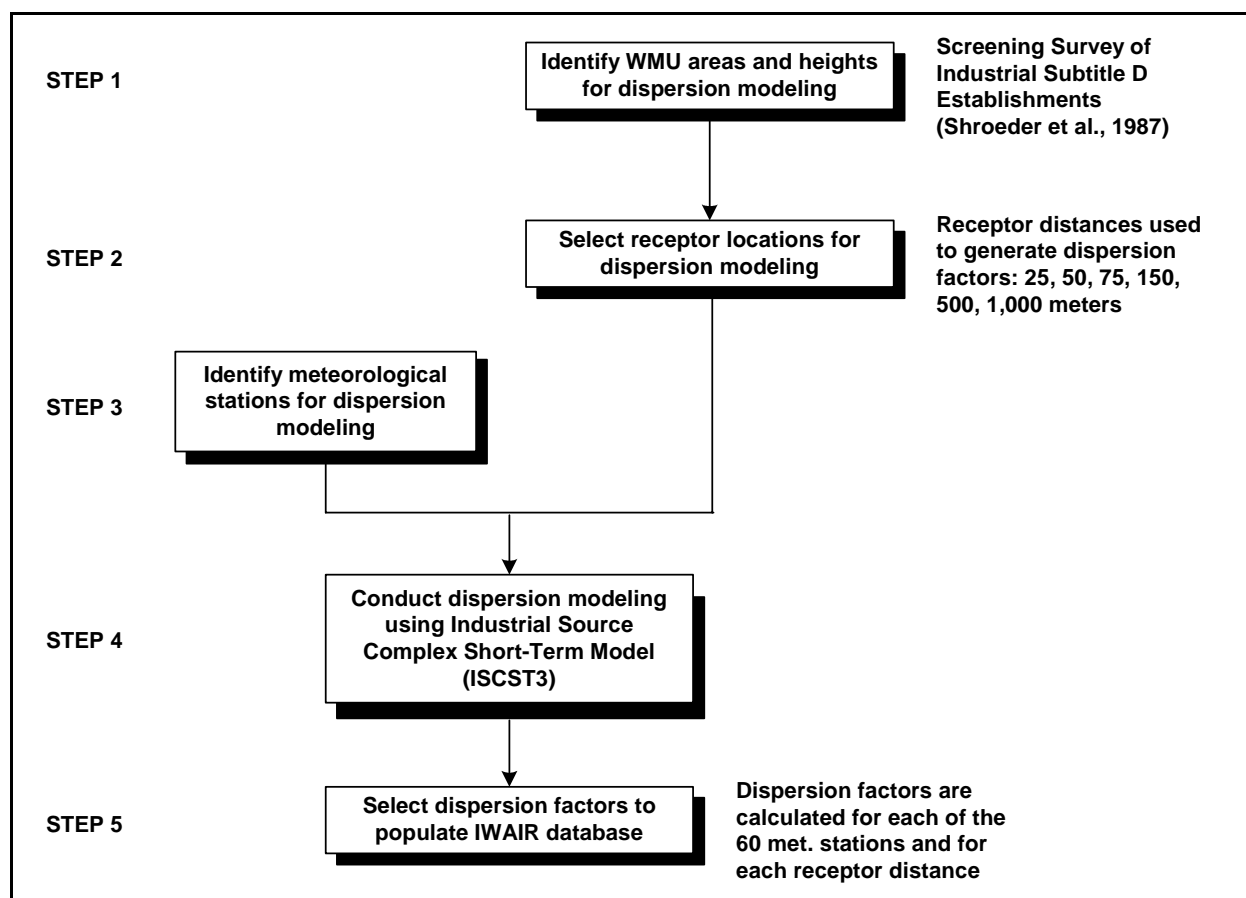### 3.1.1 Identify WMU Areas and Heights for Dispersion Modeling (Step 1)

Area and height aboveground of a WMU are two of the most sensitive parameters in dispersion modeling. To construct a database that contains benchmark dispersion coefficients, an appropriate set of "model" units to run had to be determined. This set of areas and heights was chosen to cover a range of realistic unit areas and heights and to have a high probability of achieving interpolation errors less than about 5 percent.

Land application units, landfills, and surface impoundments are all ground-level sources and are modeled the same way using ISCST3. However, waste piles are elevated sources and must be modeled separately in ISCST3. Therefore, two sets of areas were developed, one for ground-level sources (land application units, landfills, and surface impoundments), and one for waste piles. In addition, a set of heights was developed for waste piles.[1]

The primary source of data used in the analysis for determining the appropriate range of WMU areas to model was the Industrial D Screening Survey responses (Schroeder et al., 1987). These survey data provide information on the distribution of areas of nonhazardous WMUs across the contiguous 48 states. As a starting point to determine how many and what areas might be needed to adequately cover the reported range, EPA used a statistical method called the Dalenius-Hodges procedure to develop area strata from the Industrial D survey data. This method attempts to break down the distribution of a known variable (in this case, area) that is assumed to be highly correlated with the model output (in this case, dispersion factor) into a

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[1] This important distinction in the dispersion modeling between ground-level sources and elevated sources makes the use of the IWAIR surface impoundment component inappropriate to modeling tanks, which are usually elevated.

STEP 1	Identify WMU areas and heights for dispersion modeling	**Screening Survey of Industrial Subtitle D Establishments (Shroeder et al., 1987)**
STEP 2	Select receptor locations for dispersion modeling	**Receptor distances used to generate dispersion factors: 25, 50, 75, 150, 500, 1,000 meters**
STEP 3	Identify meteorological stations for dispersion modeling	
STEP 4	Conduct dispersion modeling using Industrial Source Complex Short-Term Model (ISCST3)	
STEP 5	Select dispersion factors to populate IWAIR database	**Dispersion factors are calculated for each of the 60 met. stations and for each receptor distance**

Figure 3-1. Development of dispersion factor database.

fixed number of strata in an optimal way. An area near the midpoint (in this case, the median) for each stratum is then used to represent that stratum.

No data were available on waste pile height. Best professional judgement suggested a realistic range from 1 to 10 m. (For comparison, 10 m is about the height of a 3-story building.) Within this range, seven heights were selected at 1 to 2 m intervals, with smaller intervals at lower heights.

To determine the adequacy of this initial set of areas and heights in achieving the goal of less than 5 percent interpolation error, EPA examined graphical plots of interpolation errors using one- or two-dimensional linear interpolation. These interpolation error plots were generated for three meteorological stations: Fresno, California; Minneapolis, Minnesota; and Salt Lake City, Utah. These stations were chosen to include a range of different wind roses and climate regimes to determine whether the interpolation errors differed significantly based on these factors. Very similar data patterns were seen for these three stations; therefore, EPA felt that further investigation of potential variations by meteorological station was not needed. The steps taken to generate the error plots were as follows:

1.   For each of the three sample meteorological stations, run ISCST3 to generate outputs at a set of areas (for ground-level sources) or areas/heights (for waste piles) that represent midpoints between the initial sets of areas and heights. (The midpoints are the points at which error should be the largest.) These ISCST3 outputs represent the "true" outputs for purposes of calculating interpolation errors.

2.   For each of the area or area/height midpoints, apply the interpolation algorithm (the interpolation algorithm is discussed in Section 3.2) to estimate the ISCST3 output value.

3.   Compute the percentage interpolation error, defined as

$$\frac{(\text{``true'' value} - \text{interpolated value})}{(\text{``true'' value})} \times 100 \, . \tag{3-1}$$

The error plots using the initial set of areas and heights suggested that additional areas were needed in specific parts of the distribution. Therefore, three areas were added to the set for ground-level sources, and four areas were added to the set for waste piles. A new error plot indicated that this succeeded in reducing the interpolation errors for ground-level sources to within the 5 percent goal using linear interpolation. Errors for waste piles were still as high as about 15 percent, exceeding the 5 percent goal. However, generating data for additional surface areas and heights is only one technique for reducing interpolation errors. Another way to reduce interpolation errors is to choose a more sophisticated interpolation method. This approach was taken for waste piles (and is discussed in Section 3.2), and no further additional areas were added for waste piles.

Table 3-1 shows the final set of surface areas and heights selected for the IWAIR dispersion database. Seventeen areas were modeled for ground-level sources, and 77 combinations of 11 areas and 7 heights were modeled for waste piles.

3.1.2   Select Receptor Locations for Dispersion Modeling (Step 2)

The ISCST3 model allows the user to specify receptors with a Cartesian receptor grid or a polar receptor grid. In general, Cartesian receptor grids are used for near-source receptors and polar receptor grids for more distant receptors. Because it takes a substantial amount of time for the ISCST3 model to execute with a large number of receptor points, it was necessary to reduce the number of receptors without missing representative outputs. Therefore, a sensitivity analysis was conducted on area sources to determine the receptor locations and spacings (see Appendix C for details).

The results of the sensitivity analysis of area sources show that the maximum impacts are generally higher for a dense receptor grid (i.e., 64 or 32 receptors on each square) than for a scattered receptor grid (i.e., 16 receptors on each square). For this application, however, the differences in maximum receptor impacts are not significant between a dense and a scattered

**Table 3-1. Final Surface Areas and Heights
Used for ISCST3 Model Runs**

Ground-Level Sources	Waste Piles	
Areas (m^2)	Areas (m^2)	Heights (m)
81	20	1
324	162	2
567	486	4
1551	2100	5
4047	6,100	6
12,546	10,100	8
40,500	55,550	10
78,957	101,000	
161,880	500,667	
243,000	900,333	
376,776	1,300,000	
607,000		
906,528		
1,157,442		
1,408,356		
4,749,178		
8,090,000		

receptor grid. Therefore, 16 evenly spaced receptor points on each square were used in the modeling. The sensitivity analysis also shows that the maximum downwind concentrations decrease sharply from the edge of the area source to about 1,000 meters from the source. Therefore, receptor points were placed at 25, 50, 75, 150, 500, and 1,000 meters so that a user could examine the areas most likely to have risks of concern.

Because the flat terrain option is used in the dispersion modeling, receptor elevations were not considered.

3.1.3   Identify Meteorological Stations for Dispersion Modeling (Step 3)

Meteorological data at more than 200 meteorological stations in the United States are available on the SCRAM Bulletin Board (http://www.epa.gov/scram001) and from a number of other sources. Because of the time required to develop dispersion factors, it was not feasible to include dispersion factors in IWAIR for all of these stations. Therefore, EPA developed an approach to select a subset of these stations for use in IWAIR. This approach considers the factors most important for the inhalation pathway risk modeling done by IWAIR.

The approach used involved two main steps:

1.   Identify contiguous areas that are sufficiently similar with regard to the parameters that affect dispersion that they can be reasonably represented by one meteorological station. The parameters used were

 ■   Surface-level meteorological data (e.g., wind patterns and atmospheric stability)

 ■   Physiographic features (e.g., mountains, plains)

 ■   Bailey's ecoregions and subregions

 ■   Land cover (e.g., forest, urban areas).

2.   For each contiguous area, select one meteorological station to represent the area. The station selection step considered the following parameters:

 ■   Industrial activity

 ■   Population density

 ■   Location within the area

 ■   Years of meteorological data available

 ■   Average wind speed.

Appendix D describes the selection process in detail. Table 3-2 lists the 60 stations chosen; Figure 3-2 shows the selected stations and their assigned regions for the contiguous 48 states. Appendix D provides additional maps showing regions of the 48 states on a larger scale, as well as Alaska and Hawaii.

Zip codes were overlaid on the regions, and a database matching zip codes to meteorological stations was generated for use in IWAIR. In addition, latitudinal/longitudinal coordinates of the polygons are used in IWAIR to select a meteorological station based on a facility's latitudinal/longitudinal coordinates.

Table 3-2. Surface-Level Meteorological Stations in IWAIR, by State

Station Number	Station Name	State
26451	Anchorage/WSMO Airport	AK
25309	Juneau/International Airport	AK
13963	Little Rock/Adams Field	AR
23183	Phoenix/Sky Harbor International Airport	AZ
93193	Fresno/Air Terminal	CA
23174	Los Angeles/International Airport	CA
24257	Redding/AAF	CA
23234	San Francisco/International Airport	CA
23062	Denver/Stapleton International Airport	CO
14740	Hartford/Bradley International Airport	CT
12839	Miami/International Airport	FL
12842	Tampa/International Airport	FL
13874	Atlanta/Atlanta-Hartsfield International	GA
03813	Macon/Lewis B Wilson Airport	GA
22521	Honolulu/International Airport	HI
94910	Waterloo/Municipal Airport	IA
24131	Boise/Air Terminal	ID
94846	Chicago/O'Hare International Airport	IL
03937	Lake Charles/Municipal Airport	LA
12916	New Orleans/International Airport	LA
13957	Shreveport/Regional Airport	LA
14764	Portland/International Jetport	ME
94847	Detroit/Metropolitan Airport	MI
14840	Muskegon/County Airport	MI
14922	Minneapolis-St Paul/International Airport	MN
13994	St. Louis/Lambert International Airport	MO
13865	Meridian/Key Field	MS
24033	Billings/Logan International Airport	MT
03812	Asheville/Regional Airport	NC
13722	Raleigh/Raleigh-Durham Airport	NC

(continued)

Table 3-2. (continued)

| Station Number	Station Name	State
24011	Bismarck/Municipal Airport	ND
14935	Grand Island/Airport	NE
23050	Albuquerque/International Airport	NM
23169	Las Vegas/McCarran International Airport	NV
24128	Winnemucca/WSO Airport	NV
14820	Cleveland/Hopkins International Airport	OH
93815	Dayton/International Airport	OH
13968	Tulsa/International Airport	OK
94224	Astoria/Clatsop County Airport	OR
24232	Salem/McNary Field	OR
14751	Harrisburg/Capital City Airport	PA
13739	Philadelphia/International Airport	PA
14778	Williamsport-Lycoming/County	PA
11641	San Juan/Isla Verde International Airport	PR
13880	Charleston/International Airport	SC
13877	Bristol/Tri City Airport	TN
13897	Nashville/Metro Airport	TN
23047	Amarillo/International Airport	TX
13958	Austin/Municipal Airport	TX
12924	Corpus Christi/International Airport	TX
03927	Dallas/Fort Worth/Regional Airport	TX
12960	Houston/Intercontinental Airport	TX
23023	Midland/Regional Air Terminal	TX
24127	Salt Lake City/International Airport	UT
13737	Norfolk/International Airport	VA
14742	Burlington/International Airport	VT
24233	Seattle/Seattle-Tacoma International	WA
24157	Spokane/International Airport	WA
03860	Huntington/Tri-State Airport	WV
24089	Casper/Natrona Co International Airport	WY
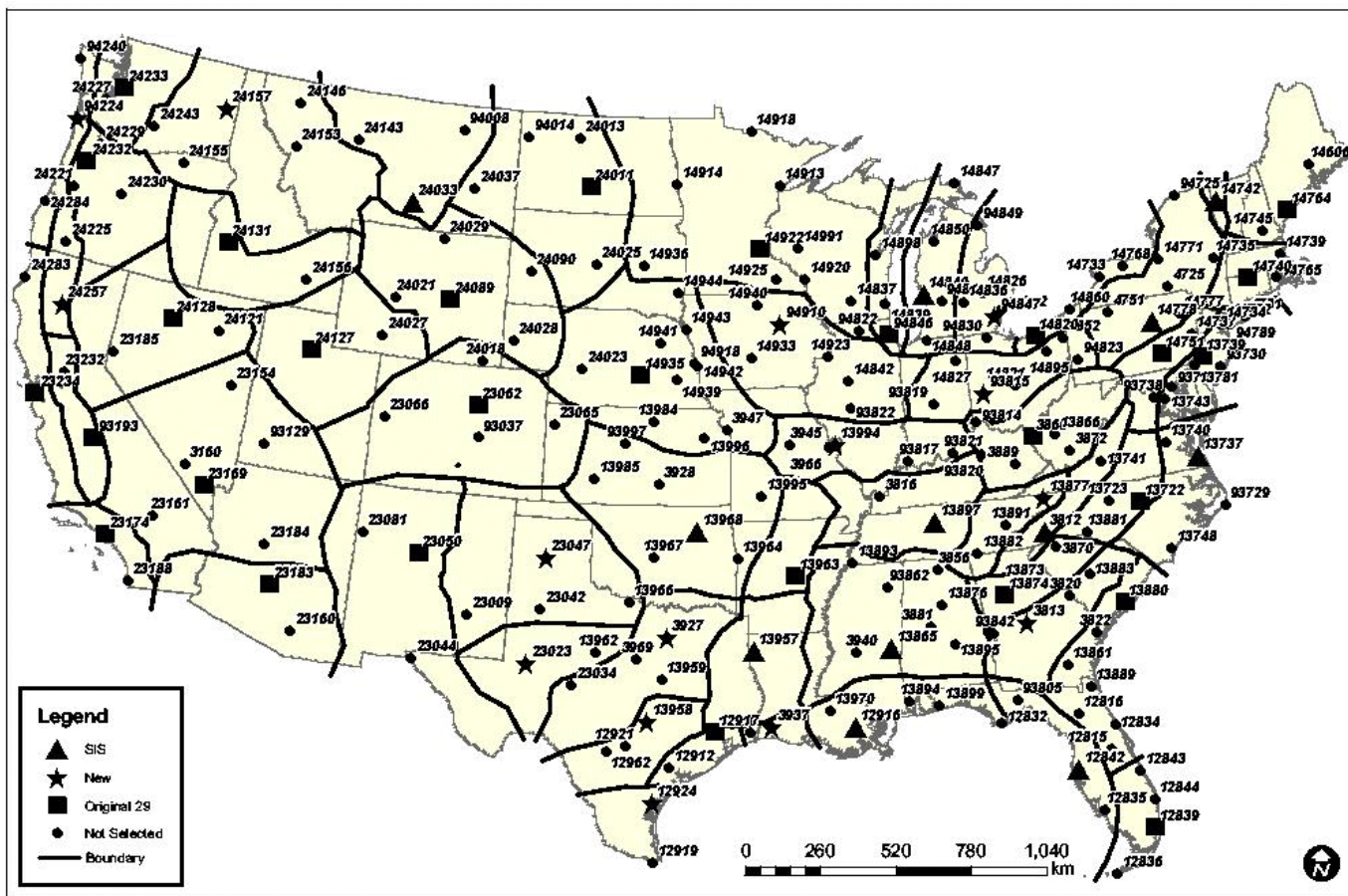
Figure 3-2. Meteorological stations and region boundaries for the contiguous 48 states.

The modeling analysis was conducted using 5 years of representative meteorological data from each of the 60 meteorological stations. Five-year wind roses representing the frequency of wind directions and wind speeds for the 60 meteorological stations were analyzed. These show that the 60 meteorological stations represent a variety of wind patterns.

Wind direction and wind speed are typically the most important meteorological inputs for dispersion modeling analysis. Wind direction determines the direction of the greatest impacts (usually in the prevailing wind direction). For IWAIR, however, wind direction is not important because only the direction of maximum air concentration is used. IWAIR determines air concentration in 16 directions, and uses only the maximum of these; the actual direction associated with that maximum is not retained. Wind speed is inversely proportional to ground-level air concentrations, so that the lower the wind speed, the higher the air concentration.

Mixing height determines the heights to which pollutants can be diffused vertically. Stability class is also an important factor in determining the rate of lateral and vertical diffusion. The more unstable the air, the greater the diffusion.

**Shape of Wind Rose for
60 Meteorological Stations**

Shape of Wind Rose	No. of Stations
Strongly directional (>20% in 1 direction)	10
Moderately directional (15–20% in 1 direction)	14
Mildly directional (10–14% in 1 direction)	26
Weakly directional (<10% in 1 direction)	10

3.1.4 Conduct Dispersion Modeling Using Industrial Source Complex Short-Term Model, Version 3 (Step 4)

This section discusses the critical parameters of the selected model, ISCST3; the results of sensitivity analyses performed to investigate several of the model parameters; and the receptor locations. Results of the sensitivity analyses are presented in Appendix C.

It is impossible to make a general statement about whether IWAIR over- or underestimates actual dispersion coefficients, as this would depend completely on site-specific factors. For some sites, it will overestimate, and for others, underestimate. Because the dispersion assumptions built into IWAIR may not be applicable to all sites, IWAIR was programmed to accommodate

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**Key Meteorological Data for
the ISCST3 Model without Depletion**

Wind direction determines the direction of the greatest impacts.

Wind speed is inversely proportional to ground-level air concentration, so the lower the wind speed, the higher the concentration.

Stability class influences rate of lateral and vertical diffusion. The more unstable the air, the lower the concentration.

Mixing height determines the maximum height to which emissions can disperse vertically. The lower the mixing height, the higher the concentration.

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user-entered dispersion factors that are a more accurate reflection of the site-specific conditions prevailing at the user's site, if these are available.

3.1.4.1 General Assumptions. This section discusses depletion, rural versus urban mode, and terrain assumptions.

Depletion. ISCST3 can calculate vapor air concentrations with or without wet and dry depletion of vapors. Modeled concentrations without depletion are higher than those with depletion. The dispersion factors for IWAIR were modeled without wet or dry depletion of vapors.

ISCST3 can model dry depletion of vapors only as a chemical-specific process. By contrast, ISCST3 can model wet depletion of vapors as non-chemical-specific process. Thus, vapor air concentrations modeled without depletion or with only wet depletion of vapors can be used for any chemical; vapor air concentrations modeled with dry depletion of vapors are chemical-specific and must be modeled separately for each chemical of interest.

Assumptions Made for Dispersion Modeling

- Dry and wet depletion options were not activated in the dispersion modeling.

- The rural option was used in the dispersion modeling because the types of WMUs being assessed are typically in nonurban areas.

- Flat terrain was assumed.

- An area source was modeled for all WMUs.

- To minimize error due to site orientation, a square area source with sides parallel to *x*- and *y*-axes was modeled.

- Receptor points were placed on 25, 50, 75, 150, 500, and 1,000 m receptor squares starting from the edge of the source, with 16 receptor points on each square.

- Modeling was conducted using a unit emission rate of 1 $\mu g/m^2$-s.

Generating chemical-specific dispersion factors that included dry depletion of vapors would have significantly limited the number of meteorological stations and WMU areas and heights that could be included in IWAIR. Dry depletion of vapors is expected to have a relatively small impact on vapor air concentration; by contrast, the differences in air concentration between different areas and different meteorological stations are considerably greater. Thus, dry depletion of vapors was not modeled, in order to include a greater number of more generally applicable dispersion factors.

A sensitivity analysis showed that the differences in the maximum concentrations with wet depletion and without wet depletion are very small, even for a wet location (less than 0.4 percent). The sensitivity analysis also shows that the run time for calculating concentrations using the ISCST3 model with wet depletion is 15 to 30 times longer than the run time without wet depletion for the 5th and 95th percentile of the sizes of land application units. (The difference is greater for larger sources.) Therefore, concentrations were calculated without wet depletion in this analysis so that a greater number of meteorological locations could be modeled and included in IWAIR.

Rural versus Urban Mode. ISCST3 may be run in rural or urban mode, depending on land use within a 3 km radius from the source. These modes differ with respect to wind profile

exponent and potential temperature gradients. Unless the site is located in a heavily metropolitan area, the rural option is generally more appropriate. Because the types of WMUs being assessed are typically in nonurban areas, the rural option was used to develop dispersion factors for IWAIR.

Terrain. Flat terrain for both the source and the surrounding area was assumed in the modeling analysis for two reasons: (1) ISCST3 can only model flat terrain for area sources,[2] and (2) complex terrain simulations in the surrounding area result in air concentrations that are highly dependent on site-specific topography. A specific WMU's location in relation to a hill or valley produces results that would not be applicable to other locations. Complex terrain applications are extremely site-specific; therefore, model calculations from one particular complex terrain location cannot be applied to another. Conversely, simulations from flat terrain produce values that are more universally applicable.

3.1.4.2 Source Release Parameters. This section describes the source parameters and assumptions used in the dispersion modeling, including source type and elevation, and source shape and orientation.

Source Type and Elevation. ISCST3 can model three different types of sources: point, area, and volume. All WMU types modeled in this analysis were modeled as area sources. Landfills, land application units, and surface impoundments were modeled as ground-level sources, and waste piles were modeled as elevated sources.

Source Shape and Orientation. The shape of WMUs facilities and their orientation to the wind affect dispersion. However, in developing generally applicable dispersion factors for use in a screening model, it was necessary to make some assumptions about shape and orientation. A square shape was chosen for the general dispersion factors in IWAIR to minimize the errors caused by source shape and orientation.

A sensitivity analysis was conducted to compare the air concentrations from a square area source, a rectangular area source oriented east to west, and a rectangular area source oriented north to south to determine what role source shape and orientation play in determining dispersion coefficients of air pollutants. The results show that the differences in dispersion factors between the square area source and the two rectangular area sources are smaller than the differences between the two rectangular sources. In addition, a square area source has the least amount of impact on orientation. Because information on source shapes or orientations is not available, a square source was chosen to minimize the errors caused by source shapes and orientations (see the sensitivity analysis in Appendix C for details).

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[2] ISCST3 can model three types of terrain for point sources: flat, simple, and complex (in simple terrain, the terrain features are all below the centerline of the plume; in complex terrain, some terrain features are at or above the centerline of the plume). However, for area sources, only flat terrain can be modeled. Typically, terrain considerations are only important for buoyant emissions from stacks, where the plume is above ground level. In that situation, terrain can affect where the plume reaches ground level, and it can significantly affect predicted ground-level air concentrations. With area sources, the plume is already at ground level, so terrain (either simple or complex) does not significantly affect ground-level air concentrations regardless of receptor distance.

3.1.5   Select Dispersion Factors to Populate IWAIR Database (Step 5)

Dispersion factors were calculated by running ISCST3 with a unit emission rate (i.e., 1 μg/m^2-s). The selected areas for each type of WMU were modeled with 60 representative meteorological locations in the United States using 5 years of meteorological data to estimate dispersion factors. Annual average dispersion factors at all receptor points were calculated.

Typically, the location of maximum impacts with respect to the source is determined by the prevailing wind direction. For each distance, the maximum dispersion factor of the 16 directions was used in the IWAIR database. For ground-level area sources (i.e., landfills, land application units, and surface impoundments), maximum annual-average dispersion factors are always located on the first receptor square (i.e., 25 m receptors). For elevated area sources (i.e., waste piles), the maximum annual-average dispersion factors are usually located on the first receptor square and occasionally located on the second or third receptor square. However, dispersion factors for all six distances are included in the IWAIR database. The annual-average dispersion factors increase with the increasing area of the sources.

Maximum dispersion factors vary with meteorological location. For landfills, land application units, and surface impoundments, the maximum dispersion factors at some meteorological locations can be twice as high as those at other locations. For waste piles, the maximum dispersion factors at some meteorological locations are more than twice those at other meteorological locations.

3.2   Interpolation of Dispersion Factor

As described in Section 3.1, a set of areas and heights were identified for modeling ground-level sources (land application units, landfills, and surface impoundments) and elevated sources (waste piles), and these were modeled for 60 meteorological locations to produce a set of dispersion factors at six receptor distances for use in IWAIR. Each dispersion factor is specific to an area, height, meteorological location, and receptor distance.

This set of dispersion factors may not include a dispersion factor that exactly matches the user's conditions. The user may be at a different meteorological location, have receptors located at different distances, or have a unit of a different area and height. For meteorological location and receptor distance, users must use one of IWAIR's 60 meteorological locations or six distances (unless they enter their own dispersion factors); there will be some error associated with this that cannot be reduced. The error associated with differences in the area and height of a unit, however, may be reduced by interpolating between the dispersion factors contained in IWAIR.

The simplest form of interpolation is a one-dimensional linear interpolation. A one-dimensional linear interpolation would estimate a dispersion factor by adjusting for a single variable (in this case, area) and assuming that dispersion factor is linear with that variable. This is done as follows:

$$\mathbf{DF} = \left(\frac{\mathbf{A} - \mathbf{A}_i}{\mathbf{A}_j - \mathbf{A}_i} \right) \times (\mathbf{DF}_j - \mathbf{DF}_i) + \mathbf{DF}_i \qquad\qquad (3\text{-}2)$$

where

DF	=	dispersion factor for specific WMU ($[\mu g/m^3]/[\mu g/m^2\text{-}s]$)
A	=	area of specific WMU (m^2)
A_i	=	area modeled in dispersion modeling immediately below area of specific WMU (m^2)
A_j	=	area modeled in dispersion modeling immediately above area of specific WMU (m^2)
DF_i	=	dispersion factor developed for area i ($[\mu g/m^3]/[\mu g/m^2\text{-}s]$)
DF_j	=	dispersion factor developed for area j ($[\mu g/m^3]/[\mu g/m^2\text{-}s]$).

Linear interpolation can also be two-dimensional to adjust for two variables (in this case, area and height).[3] Finally, nonlinear interpolation (both one- and two-dimensional) may be performed if the output variable (dispersion factor) is not linear with the input variables (area and height).

For ground-level sources, EPA analyzed interpolation error using a one-dimensional linear interpolation (see Section 3.1.1). This analysis indicated that interpolation errors of 5 percent or less could be achieved using linear interpolation on the areas identified in Table 3-1.

For waste piles, a similar analysis of interpolation errors using two-dimensional linear interpolation indicated that a very large number of areas would have to be modeled to reduce interpolation error to 5 percent using linear interpolation techniques. Therefore, EPA chose to implement a two-dimensional spline approach instead. A spline is a nonlinear interpolation technique that takes into account other points near the point of interest rather than just the two adjacent ones (as in linear interpolation). A cubic spline was used in IWAIR. The equations for implementing a spline are standard but complex; see, for example, Mathews (1992), Section 5.3, for details. This approach tends to be more accurate because it accounts for the nonlinear nature of the relationship between area or height and dispersion factor. However, it may behave unpredictably, producing inaccurate results, especially near the edge of the surface (where it has fewer nearby data points to work from) or where the gradient of the surface is steep (i.e., relatively large changes in dispersion factor occur for relatively small changes in area or height). Repeating the error analysis using a two-dimensional spline indicated that interpolation errors of 5 percent or less could be achieved using the areas identified in Table 3-1.

However, as noted above, a spline can occasionally produce inaccurate results. As a check on the spline method, EPA also included the two-dimensional linear interpolation

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[3] For a given area, *A*, and height, *h*, the algorithm first performs a one-dimensional linear interpolation on height for the two available areas adjacent to *A*. From these two interpolated dispersion factors, another one-dimensional linear interpolation is then performed in the area domain.

algorithm in the IWAIR code. The linear interpolation is known to underestimate dispersion factors at all times; therefore, it provides a useful check on the spline. Thus, at an interpolated point, both a spline interpolation and a two-dimensional linear interpolation are performed. In general, the spline's estimate is preferred and used, but some tests (e.g., negative splined concentration) and comparisons against the linearly interpolated value, as well as the values at the surrounding four grid points, are made first. The linear interpolation value is used, and the user notified of that fact, if the splined air concentration is

- less than or equal to zero,
- less than the linear interpolated value,
- less than the minimum of the four nearest points in the database, or
- greater than the maximum of the four nearest points in the database.